

# ***A Few Mine Related Considerations For An Enhancement Of SR 80, Near Bisbee Arizona***

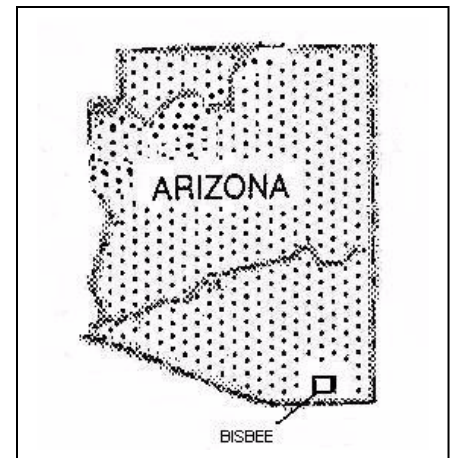
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## **Abstract:**

During the last two years I have been involved with the planning of a highway enhancement project that had the potential to be impacted by former underground and surface mining workings. The relative importance of these features on the project design varied from merely being aware of these features to having a controlling effect on the design process. This paper will outline part of the information that has been shared with the project stakeholders.

## **Location**

The area of discussion is located near the historic community of Bisbee, Cochise County, Arizona. The project is located adjacent to SR 80 between Mileposts 341 to 342.5 and follows the boundary of the Lavender Pit copper mining facility.



ADOT Project F-016-1 (11) realigned SR 80 in 1961 along the eastern boundary of the Lavender Pit to accommodate expansion of mining activity. The Lavender Pit began stripping operations in 1954 and included the Sacramento Pitt, which began excavations in 1913. Exhaustion of mineable material and the high cost of continued operation forced closing of the facility in 1975. The pits occupy an area that was formerly excavated by underground methods, which include stopeing, block caving, and top slicing methods. Some of these abandoned underground works are visible in the pit's wall.

## **Geology of Bisbee Area** (*Abstracted from Mortensen, 2002*)

The oldest rock units exposed in the Bisbee are Mesoproterozoic (ca. 1.7 Ga) fine grained metaclastic rocks of the Pinal Schist. This formation is unconformably overlain by a nearly complete Paleozoic section approximately 2km thick, comprising, from base to top, the Abrigo Limestone (Cambrian), Bolsa Quartzite (Cambrian-Ordovician), Martin Limestone (Devonian), Escabrosa Limestone (Mississippian) and Naco Group (Pennsylvanian-Permian). The Pinal Schist and Paleozoic sedimentary rocks are in turn overlaid with marked angular unconformity by continental, mainly clastic sedimentary rocks of the Middle (?) Jurassic to Cretaceous Bisbee Group, which in this area

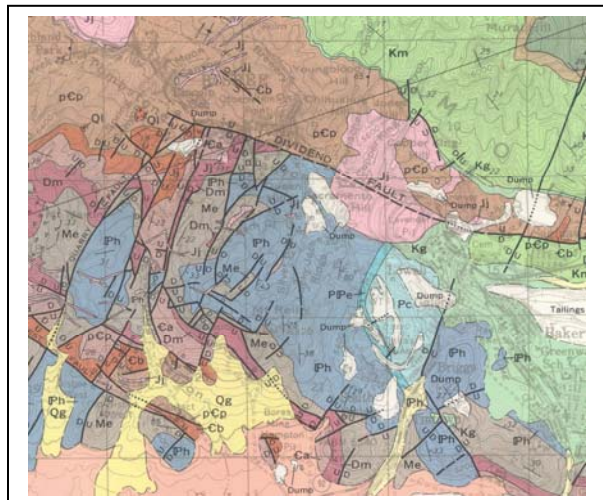
comprises the Glance Conglomerate and an overlying sequence of clastic and chemical sedimentary rocks. The Pinal Schist and Paleozoic strata have been intruded by a number of different intrusive bodies or complexes, the largest of which are the Juniper Flat pluton northwest of Bisbee, and the Sacramento stock, which underlie much of the Lavender Pit and the Cochise deposit area immediately to the east. Numerous smaller equigranular to porphyritic felsic intrusions have been mapped in the Bisbee area, and most of these cut the Paleozoic and older rocks and are thought to predate the Bisbee Group.

The dominant structure in the area is the west-north west trending Dividend Fault. This southwest dipping structure has an estimated displacement of 3,000 feet and separates the Pinal Schist from the Paleozoic materials. According to Keith and Wilt, "the entire south wall of the Lavender Pit has been down faulted along the Dividend fault which traces through the center of the Lavender Pit. The north wall of the pit is in the up thrown Pinal Schist and is intruded by the Sacramento stock." According to the authors, several stages of mineralization and faulting has resulted in a deposit resembling a semicircle with radiating offshoots of mineralized fracture zones, positioned roughly symmetrical with the Dividend Fault. The overall dimensions for these features range from up to 2,000 ft vertically, 500 ft horizontally and may extend up to 12,000 feet in length.

Keith and Wilt (1978) reports that the road cuts of US 80 traversing the eastern flank of the Lavender pit as spectacular examples of "alteration related to porphyry copper mineralization in the alkali granite of the Sacramento Stock." "The surfaces of the hills in the vicinity are covered by a bright red oxidized zone which follows the contours of the hills. This material extends down into the primary altered rock along fractures. Primary, altered, gray colored, (quartz-sericite-pyrite) material of the Sacramento Stock is pervasively exposed below this zone The American Geological Institute describes alteration as any change in the mineralogical composition of a rock brought about by physical or chemical means, especially by the action of hydrothermal solutions and as a secondary or 'supergene' (*meaning formed near the surface, commonly by descending solutions*) change in rock or mineral. Therefore, portions of the Sacramento stock have been chemically changed (altered) several times before exposure by excavation.



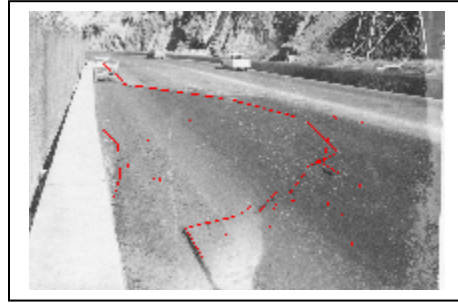
Red oxidized zone above and overlying (gray) hypogene alteration in the Sacramento Stock



Geologic Map from: Hayes and Landis

### **Highway Background Information**

Two years after ADOT Project F-016-1 (11) was constructed in 1964, a 200-foot long arcuate crack propagating toward centerline had been reported and a landslide was progressing along a parallel trace of the Dividend Fault zone.



The stability of the site has been an intermittent concern since construction in 1961. The records indicate that there was some disagreement over the methods to mitigate the slide conditions. The project file contains a number of letters that refer to maintenance work by both the mining company and ADOT through 1966. In 1987, a Geotechnical Investigation (Report No. 87-13) was conducted to investigate a 150 ft long crescent shaped crack in the pavement in the same general vicinity. The report indicated that in 1978, the mining company repaired a section of settling highway by installing steel bars into grouted drill holes. A large “slippage of the pit slope was observed” Inclonometers were installed at the site and have been monitored intermittently since that time.

In February 2003, a Design Concept Report was issued to provide new pedestrian access along SR 80 to connect the communities of Old Bisbee and Lowell. Unfortunately the enhancements proposed to widen the highway on the existing embankment section that formerly experienced settlement and landslide activity. Additionally, the mining company indicated that there was concern about subsidence in the Lowell area. A site visit to the area confirmed the presence of tension cracks outside the right of way fence in several sections of the Lavender Pit in proximity to the proposed improvements.

Because this project was only in the pre-design stages, it was convenient to bring these conditions to the attention of the project stakeholders and effectively suggest alignment changes to avoid a potential problem.



**Above:** Settlement features developing inside fence line. **Right:** Aerial view of the Lavender Pit near Lowell. Apparent distress features highlighted red

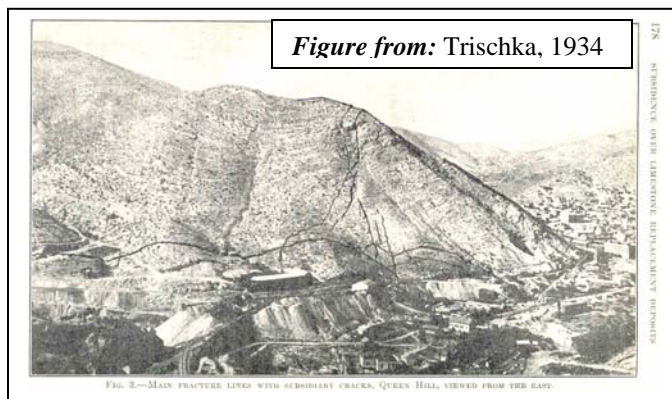




## ***Air Photo Interpretation and Rediscovery of Subsidence on Queen Hill***

*(With some historical citations)*

At the time of my involvement with the design of the new pedestrian facilities, a set of air photographs for this section of the highway became available. I examined the photographs and enlarged the images (with a digital scanner) of the route of the proposed improvements to look for signs of highway infrastructure distress. Besides the settlement features apparent in the area just beyond the fence in the Lowell area, numerous other fissures, crack and wide fractures were exhibited north east of the highway in the vicinity of the Queen Mine Tour. (Queen Hill) Initial reactions to the observed features were eye opening. However a diligent records search indicated that these features were reported in the technical literature over 70 years ago.

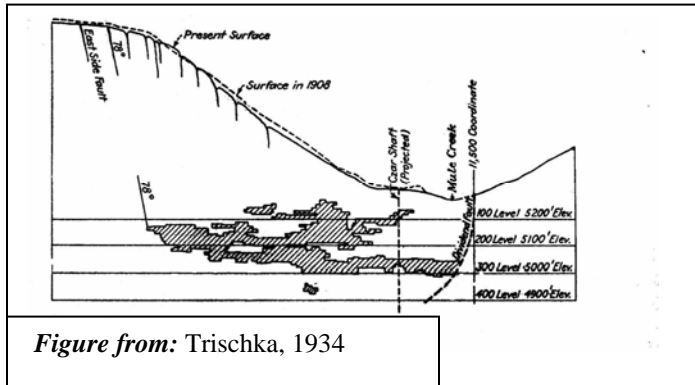


When originally reported by Carl Trischka in 1934, a display of crescent shaped open cracks and fissures curved up across the ridgeline of Queen Hill and extended to the southeast a length in excess of 1200 feet. Although no mention of the width of the fissure is given, historical photographs in the vicinity suggest they may have reached at least 10 feet in width. Mr. Edward Wisser (1927) in *Economic Geology* Vol. XXII, believed that a process referred to as “Oxidation Subsidence”, preweakened the Paleozoic sedimentary rocks by creating void space and initializing vertical and semi-horizontal (doming) discontinuities in the rocks in the time period before mining began. The mining of the deposits and the methods available at the time reactivated these incipient weaknesses and accelerated subsidence in the area.



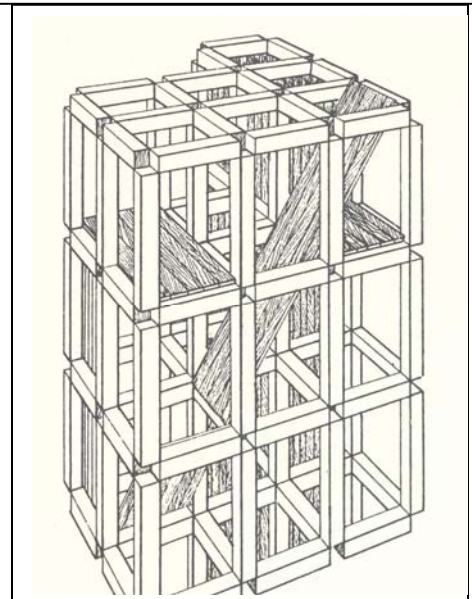
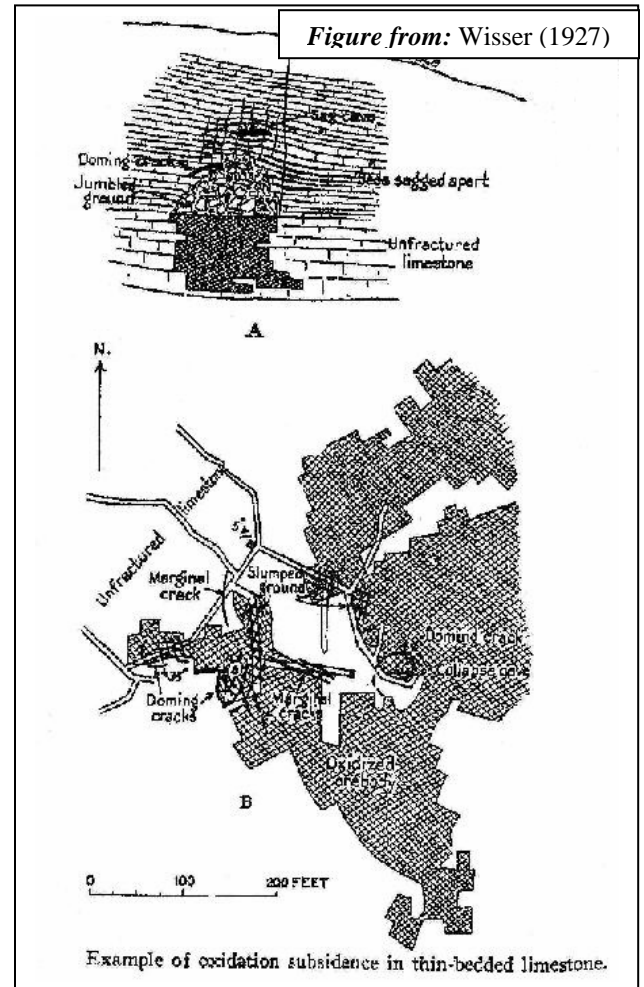
***Figure from: Cauty and Greely, 1987***

Wisser (1927) believed that the sulfide bearing metal deposits decreased in volume, creating void space around the enclosing materials. The Paleozoic sedimentary rocks were weakened by this process and initialized the formation of vertical and semi-horizontal (doming) discontinuities in the rocks prior to the start of mining activities.



The methods employed to mine and stabilize the workings have been described by Bailey (1983).

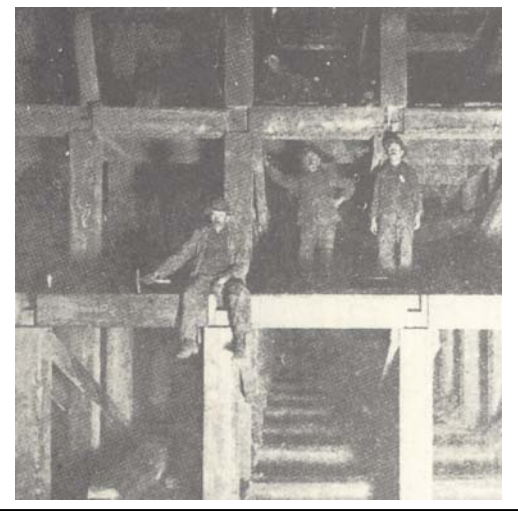
“The square-set method of stoping was adopted by the Copper Queen Mining Company in the early 1880's and was used almost exclusively until 1912, where the top slicing and caving came into limited use.” “As the name implies, square-sets were no more than a cubic lattice-work of timbers, mortised together to support heavy ground.” Although expensive square-setting readily adapted itself to irregular ore bodies, where on the floor the ore may widen out and on the next (set) pinch, while on the third (set) it may be high grade but include considerable waste, Square-sets had disadvantages too. The method served well only when the ground was quiescent. When earth wanted to move, as was the tendency at both Virginia City (Nevada) and Bisbee, nothing whatsoever could restrain it. Square-sets were also vulnerable to fire, and dry rot created by damp heat generated by decomposing ore. Nevertheless, square sets, worked especially well when miners kept them “gobbed up” or filled with waste as tight against the working surface as practice to minimize wobble.”



*Figure from: Bailey 1983*

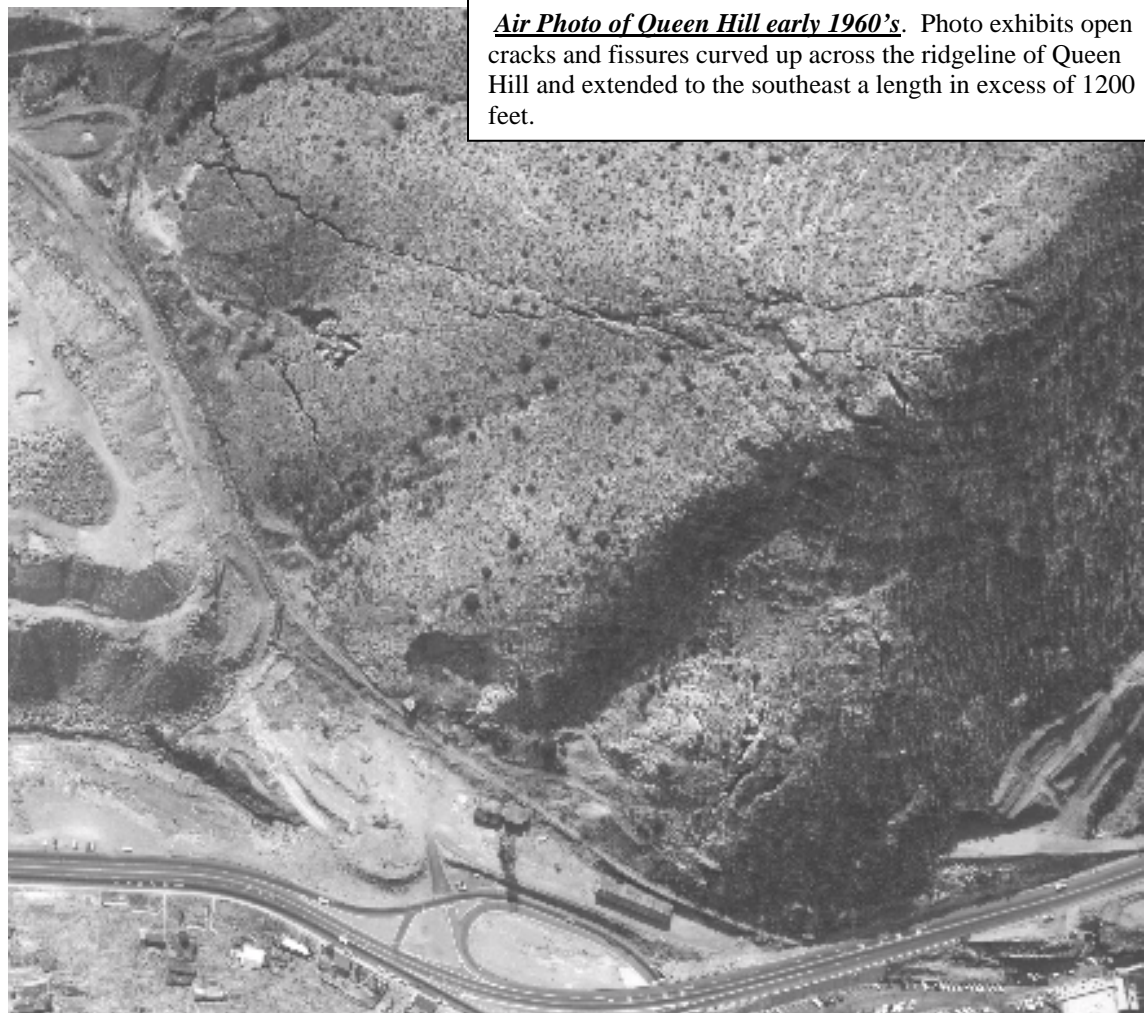


These conditions were confirmed by Trischka (1934). “In the early square-set stopes, very heavy timber was used and close filling of mined-out areas was carefully followed out, despite these precautions, supports frequently were inadequate and caving of the overburden occurred. There is little doubt that in many cases this was due to the presence or pre-mining lines of weakness extending upward from considerable distance above the stopes. As the square-set stopes spread over larger areas, subsidence extended to the surface. Close filling reduced the subsidence but could not prevent it.”



Square-Set images courtesy Baily 1983

“All the various mining operations including open-pit work in porphyry ore and underground mining of limestone replacement and porphyry ores have had their influence in disturbing the surface. As these influences frequently overlap, and because the surface disturbance is continuous over practically all ore occurrences, it is virtually impossible to chose an area sufficiently isolated to ascribe the amount of subsidence to any definite volume of ore removed.”



**Air Photo of Queen Hill early 1960's.** Photo exhibits open cracks and fissures curved up across the ridgeline of Queen Hill and extended to the southeast a length in excess of 1200 feet.

Consequently the practice in the area in the time prior was to stabilize the mine workings sufficiently to continue operation. Changes and adjustment to the topographic surface were accepted as incidental to mining. Trischka concluded his paper by stating “ Subsidence following mining must be taken into account, not only as to its effects on the surface where roads, buildings, and other equipment must be preserved but also in preserving shafts by establishing circles of varying diameters around them within which no ore is extracted until the shaft is ready to be abandoned.”

### **Future Considerations**

Blodgett and Kuipers (2000) citing Singh have reopened the question of subsidence in hard rock mining. They state, “ There are several misconceptions about subsidence. For example, depth of the mine (as measured by the thickness of the overlying strata) is often suggested as a prevention or mitigation measure. Similarly, the extraction area is often correlated with the size of the subsidence area. However, according to Singh, mining at any depth can result in subsidence, and the affected surface area is generally larger than the extraction area (SME, 1986)”

“Stope mining combined with the development of audits, drifts, and shafts, has historically been the most prolific form of hard-rock metals mining and has been done at both large and small scale, The subsidences created by stope mining is usually the result of cave-ins, inadequate support, pillar robbing, mining too close to the surface, and the eventual collapse of the workings over time as the inevitable consolidation of the strata takes place.” Although there is clearly a predisposition for subsidence to occur in the vicinity of Queen Hill, mining practices at the time were certainly contributory to overall subsidence in the vicinity. However they probably were the best available technology at the time.

### **General Comments and Recommendations**

It can be concluded that preliminary investigations into highway improvement projects in the vicinity of previously mined areas need to be performed with special concern towards identifying potential sources of disturbed areas. Project team members should include technical expertise that bridges multiple disciplines. A dissertation by Madan Singh (1992) provides a guide to all the disciplines that might be necessary to mitigate a subsidence condition. In the case of this project, both in-house geologic and private mining expertise provided information to the project stakeholders.

In previously mined areas, background investigation should be expanded to take into account all the technical information available which may impact project design. Routinely, geologic and mining information is available from government sources that are not directly connected to highway design and construction. These documents may also cover mining activity that predates the superposition of a highway onto a previously mined area. In this project, descriptions of the subsidence features were reported in professional mining journals.

Air photo interpretation has been a reliable indicator of geologic conditions for many years. Its direct application towards identifying suspected mine related disturbances features should not be overlooked or discounted. In many cases, aerial photography is utilized to create the construction drawings. Additionally, acquisition of older air photographs and comparison with recent materials could reveal mine related features that are masked by the effects of time. With the extensive use of digital scanners and personnel computers, reasonably serviceable enlargements can be made to expedite this type of study from existing air photo archives and 35 mm prints. With this project, we were fortunate to possess good quality air photo diapositives from the original construction, (1962), and recent air photographs from 2000. Also, reasonably good panoramic photographs were available from the technical journals.

Designs should also look at the existing site conditions with a bit more scrutiny when using standard drawings. The conditions that are responsible for the mineralization may have deteriorated the basic conservative parameters upon which the standard drawings have been developed. Specifically in this case, the alteration of the granite, fault breccias, and un-controlled water seeps and unstable embankment could all have contributed to the previously described highway settlement.

When appropriate, long-term changes to the bearing capacity of structural foundations in areas that have previously been undermined should also be considered. Many times highway routing remains intact long after mining firms are no longer operating.

Mine features are often obliterated or covered up with the passage of time and the highway construction process. The mere fact that they are not visible does not mean they do not exist.

The effects of these features on the present and future projects in the vicinity can now be viewed in a more enlightened context. At the very least, improvements to this route can be planned with these conditions in mind.



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